NATO

ADVANCED STUDY INSTITUTE

PROGRAM

Physics and Materials Science of High Temperature Superconductors

Kongresshotel Residenz

Bad Windsheim, FRG
13-26 August 1989

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This report contains the conference program, a list of the abstracts of papers, the poster session abstracts and a list of the participants. The program stressed the physics and materials science of high temperature superconductors.

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NATO

ADVANCED STUDY INSTITUTE

PROGRAM

Physics and Materials Science of High Temperature Superconductors

North Atlantic Treaty Organization

ADVANCED STUDY INSTITUTE

Physics and Materials Science of High Temperature Superconductors

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Program

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12:00	First bus leaves Nurnberg Airport
12:30	First bus leaves Nurnberg Train Station
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16:30	Second bus leaves Nurnberg Train Station
19:00	Reception with the Mayor of Bad Windsheim
20:30	Dinner

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07:30 - 09:00	Breakfast (Schedule half hour later than normal)
09:00 - 09:30	Welcome, procedural discussions
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11:00 - 11:30	Break
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19:00 - 19:30	S. K. Patapis: Thermodynamic Fluctuations and Critical Behaviour of Ceramic High T_C Superconductors Out of Electrical Resistivity and Thermoelectric Power Measurements
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10:30 Buses depart for Rothenberg, Creglingen and Dinkelsbühl (Cost: 10 DM/person)
18:00 Buffet Dinner on Terrace

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11:30 - 12:00 D. Mitzi: Oxygen and Ion Doping in $Bi_2Sr_2CaCu_2O_{8+\delta}$ Single Crystals
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11:30 - 12:00 Y. Watanabe: Mid-Infrared Reflectivity of Single Crystal $YBa_2Cu_3O_7$ and Related Compounds
12:00 - 12:30 M. Hahn: Fabrication Techniques and Physical Properties of Thin Film High T_c Superconductors
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11:00 - 11:30 D. Divecha: Synthesis of High Temperature Superconductor Wires via Plastic Deformation
11:30 - 12:00 M. Trudeau: Amorphous Metallic Precursors by High Energy Ball-Milling for High T_c Superconductors
12:00 - 12:30 G. Bogner: High T_c Superconductors: Power Applications
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11:00 - 11:30 D. Keeble: EPR and Microwave Absorption Measurements on Single-Crystal Ti-Ca-Ba-CuO
11:30 - 12:00 H. Siebold: Superconductivity in Medicine
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17:00 - 18:30 B. Stritzker: Thin Film Preparation by Laser Evaporation and Sputtering
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20:00 Dinner

SATURDAY, 26 August 1989

Departures Bus transportation to Nurnberg Airport will be arranged
(Cost: 10 DM/person)

Abstracts

OPEN ORBIT AND MAGNETIC BREAKDOWN EFFECT.

K. C. Bordoloi and F. A. Bynum,
Electrical Engineering Department, University of Louisville,
Louisville, KY

The purpose of the presentation of this paper is to describe the theory of open orbit and the magnetic breakdown effects in general. That theory has been verified by observations in experimental work on pure Sn under liquid helium temperatures. The asymptotic behavior of magnetoresistance and hall effect under high magnetic field and low temperature (below the λ point of liquid helium) were related to the theory. Subsequently, a number of other researchers have also verified these theoretical predictions.

Notes

FLUCTUATION TORQUE FOR H.T.S. IN HIGH MAGNETIC FIELDS.

T. Mishonov,
Joint Institute for Nuclear Research, Head Post Office, Post Office Box 79,
Moscow, USSR

The fluctuation torque (FT) for anisotropic superconductors is calculated in the framework of the Ginzburg-Landau (GL) theory. There it is shown that the measurements of FT give an alternative method for determination of the upper critical field H_{c2}. An estimation for strength of the magnetic field is given and assuming certain deviations from the local GL theory, it is possible to obtain an information for Cooper pair form factor.

Notes

PHENOMENOLOGICAL THEORY OF SUPERCONDUCTIVITY.

C. Deutcher,
Physics and Astronomy Department, Tel-Aviv University,
x-Aviv, 69978 Tel-Aviv, Israel.

The applicability of mean field Ginzburg-Landau theories to the new oxides will be at the center of this lecture, with emphasis put on the special role played by the short coherence length. Experimental methods used to determine the Landau-Ginzburg parameters, such as penetration depth, coherence length, and critical fields will be reviewed in a critical way. The anomalous electro- magnetic behavior of the oxides such reversible magnetic behavior of polycrystals and single crystals, low critical current densities, magnetization relaxation, and microwave absorption at low fields will be discussed. The short coherence length implies a great sensitivity of the superconducting order parameter to crystallographic defects on the atomic scale, contrary to the behavior of conventional long coherence length superconductors. Based on the known structure in the oxides, the anomalous superconducting properties in the presence of magnetic fields will be discussed.

Notes

THERMODYNAMIC FLUCTUATIONS AND CRITICAL BEHAVIOR OF CERAMIC HIGH T_C SUPER-CONDUCTORS OUT OF ELECTRICAL RESISTIVITY AND THERMOELECTRIC POWER MEASUREMENTS.

S. K. Patapis,
Physics Department, Solid State Section, 104 Solonos Str., University of Athens,
Athens 10680, Greece;
M. Ausloos,
Institute de Physique, B.5, Universite de Liege, B-4000 Liege, Belgium;
C. Laurent,
Institute Montefiore B.28, Universite de Liege, B-4000 Liege, Belgium;
C. Politis,
Kernforschungzentrum, Institute für Nucleare Festkorperphysik,
Postfach 3640, D-7500 Karlsuhe, FRG.

We report fine measurements of resistivity and thermoelectric power on ceramic superconductors of the YBaCuO and BiCaSrCuO system. The data taken in the critical temperature regions are very close to T_C and from them physical information may be extracted with reference to the dimensionality of the thermal fluctuations and the general critical behaviour of the material.

Concerning the electrical resistivity, precise measurements are presented on samples of $Y_1Ba_2Cu_3O_{7-y}$ and $B_{2-x}Pb_xCa_2Sr_2Cu_3O_{10}$ superconducting material from room temperature down to the percolation temperature. The temperature behavior of the rounding of the resistivity or the excess conductivity at T_C is examined in terms of the Aslamazov-Larkin theory. Since the number of the data points taken is large, it allows us to analyze the temperature derivative variation of electrical resistivity as a function of the reduced temperature ε (where $\varepsilon = |T - T_C| / T_C$) on a log-log scale in order to extract the superconductivity fluctuation dimensionality regimes. Similar precise measurements are taken for the thermoelectric power of the above materials. The data are analyzed as above, e.g., the temperature derivative of the thermoelectric power at T_C is analyzed on a log-log plot. We show that similar regimes exist for both transport coefficients (resistivity and TEP) but differ between YBaCuO and (BiPb) CaSrCuO polycrystalline composites. The same measurements are now going to extend to monocrystal of the BiCaSrCuO system.

Notes

CRYSTAL CHEMICAL ASPECTS AND SUBSTITUTIONS IN HIGH T_C CUPRATES.

B. Batlogg and R. J. Cava
AT&T Bell Laboratories
Murray Hill, NJ 07974

Superconductivity in the cuprates is induced by introducing "holes" or "electrons" into compounds which contain formally divalent copper. This is frequently done by substitution of heterovalent ions for the non-copper metals. Examples are (La, Ba)CuO_4 and (Nd, Ce)$_2CuO_4$. Alternatively, the oxygen content is varied, as in $Ba_2YCu_3O_x$, or oxygen is substituted by fluorine, as in $Nd_2Cu(O,F)_4$. Although the overall electron count is varied, complications can arise on a microscopic scale which is relevant to electron properties, because the superconducting coherence length is so short (~15Å). The implications of electronic (in)homogeneity will be discussed, particularly with respect to interpretations of experimental results in terms of a continuously varying electron concentration.

Notes

JAHN-TELLER EFFECT AND OSCILLATORY SOLUTIONS OF THE BCS GAP EQUATION.

M. Weger and R. Englman,
Physics Department, Hebrew University,
Jerusalem, Israel.

The Jahn-Teller effect implies a degeneracy of two (or more) states which is lifted by a symmetry-breaking interaction. In the language of BCS theory, this implies a NEGATIVE electron-phonon coupling constant λ. Contrary to expectations, a negative λ gives rise to a BCS-like bound state. However, the gap function $\Delta(\varepsilon)$ oscillates sharply as a function of ε. These oscillations imply a retardation that is much more effective than in ordinary BCS theory and they reduce the Coulomb repulsion very effectively even if the frequency of the frequency of excitations (phonons or electronic excitations) ω_0 is not much smaller than ε_F. These solutions seem to account for the superconductivity of the cuprates.

Notes

EFFECT OF TEXTURE AND DENSITY ON GRAIN COUPLING OF SINTERED Y-Ba-Cu-O SUPERCONDUCTORS.

M. Nikolo,
University of Colorado,
Boulder, CO.

The ac susceptibility of sintered $Y_1Ba_2Cu_3O_{7-\delta}$ pellets was measured as a function of grain orientation at the surface (texture) and pellet density (determined by compaction pressure). The susceptibility measurement distinguishes between the intrinsic superconducting grains and the weakly superconducting intergranular component. There is a positive shift in the critical temperature of the coupling component when a pellet surface is textured. This may be explained in terms of anisotropy and improved grain-boundary shielding currents. In the second part of the experiment, for samples prepared using a series of compaction pressures, the coupling critical temperature increases, up to a point, with increasing pellet density. These results can be attributed to improved contact area between the grains and a corresponding increase in the grain-boundary shielding currents.

Notes

BCS THEORY AND BEYOND.

Dierk Rainer,
University of Bayreuth, Germany

This lecture reviews on an elementary level a few basic aspects of the microscopic theory of superconductivity. It focuses on concepts, well established results, and open questions which seem to be relevant for high T_c superconductors. Commonly used notions are introduced such as: *unconventional superconductivity, new mechanisms,* negative-U models, strange excitations, separation of charge and spin, quasiparticles, particle-hole coherence, bag models and and (bi-)polarons, magnetic mechanisms, strong-coupling effects. The lecture gives a brief introduction to BCS-theory, other traditional approaches, as well as alternative theories of superconductivity, and discusses questions like: Does the traditional BCS-theory work for highly correlated two-dimensional electrons? When does it fail? What are the fingerprints of new kinds of superconductivity? Do we need completely new approaches? Is there a theory of T_c? What limits does theory put on T_c? What is the evidence for a new mechanism in high T_c materials? Can we measure the mechanism? Is it important to know the mechanism?

Notes

SUPERCONDUCTING AND ANTIFERROMAGNETIC INSTABILITIES IN THE SLAVE BOSON APPROACH TO THE HUBBARD MODEL-FUNCTIONAL INTEGRAL FORMULATION.

Piotr Wrobel,
Institute for Low Temperature, Polish Academy of Sciences,
Post Office Box 937, 50-950 Wroclaw 2, Poland.

The possibility of superconductivity-antiferromagnetism coexistence in a one-band model of highly correlated electrons is investigated. The effective 2D antiferromagnetic Hamiltonian of the form that applies in large-U limit of the Hubbard model is used as a starting point. Superconducting (SC) and antiferro-magnetic (AF) order parameters are expressed in terms of auxiliary operators which correspond to spinons and holons describing spin and charge degrees of freedom in the investigated system. The mean field theory in the functional integral formulation is developed. It is shown that antiferromagnetism is confined to a region near half-filling. The SC state stabilizes upon changing the electron density of states from the configuration of the half-filled to half-filled band. The SC-AF coexistence is confirmed by constructing a phase diagram-temperature versus band filling.

Notes

ELECTRON MICROSCOPY APPLIED TO THE STUDY OF STRUCTURES AND MICROSTRUCTURES OF SUPERCONDUCTORS.

S. Amelinckx,
Electron Microscopy, University of Antwerpen,
RUCA, Groenenborgelaan 171, B2020 Antwerp, Belgium.

Electron microscopy and electron diffraction have played a significant role in the elucidation of the structures and microstructures as well as in the study of defects in the new high temperature superconductors. In our contribution, we will discuss applications to the different families of superconducting materials.

$YBa_2Y_3O_{7-d}$ (The 1-2-3 Compounds)

The structure is an orthorhombic derivative of the cubic perovskite structure. At room temperature the crystals are almost invariably twinned. This was discovered by diffraction contract observations combined with electron diffraction and independently by means of x-ray diffraction. The twinning can be understood in terms of an order-disorder transition of the composition induced vacancies on the oxygen sublattice. The ordering of these ``structura'' vacancies causes a reduction in symmetry from tetragonal to orthorhombic, leading in turn to breaking up of the structure in twin domains. The crystallography of the twinning texture follows from simple group theoretical considerations.

The phase transition was studied *in-situ* in the electron microscope and a video tape showing different stages in the transformation was recorded. From these observations, it was concluded that the transition is partly diffusion controlled and partly diffusionless.

The same order-disorder transition on the oxygen sublattice was shown to give rise to superstructures in the oxygen deficient materials ($\partial = 0 - 0.6$).
Orthorhombic as well as tetragonal superstructures were discovered by means of electron diffraction as well as by direct imaging of the structures. The 2ao orthorhombic superstructure is responsible for the 60K superconducting transition.

The Compounds $Bi_2Sr_2Ca_nCu_{n+1}O_{2n+6}$

The basic structure of these layered compounds is related to that of perovskite. It consists of perovskite blocks separated by bismuth oxide bi-layers having a NaCl-like structure. The structure determined by x-ray diffraction was found to be an average structure only. High resolution electron microscopy and electron diffraction revealed that the actual structure is displacement modulated, the lattice planes being visibly wavy. As a result, the real structures have either monoclinic symmetry (n = 0) or ortho-rhombic symmetry (n = 1,2) as compared to the tetragonal symmetry of the basic structure.

This reduction in symmetry as a result of the modulation gives rise to the formation of ``modulation twins''. Depending on the value of n, either one (for n = 1,2) or two (for n = 0) kinds of interfaces can be distinguished.

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Notes

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Compounds with different c-parameters, i.e., with different n-values occur intimately intergrown. An empirical relation seems to exist between the n-value and the T_c temperature which can explain some of the details of the resistivity versus temperature curve. The intergrowth hampers the preparation of single phase material.

By means of image simulations, it was shown that the most probable origin of the modulations is the mismatch between the perovskite lamellae and the bismuth oxide bilayers. This may induce the uptake of excess oxygen in the BiO-layers relieving in this way the stresses due to the mismatch.

The Compounds $Ti_2Ba_2Ca_nCu_{n+1}O_{2n+6}$

The average structure of the Ti-compounds is very similar to that of the Bi-compounds, but the real structure, as revealed by electron diffraction, is modulated in two mutually perpendicular directions. Whereas in the Bi-compounds, the modulation is one-dimensional it is two-dimensional in the Ti-compounds.

Different members of the homologous series with n = 2,3,4 were found and their presence correlated with the resitivity versus temperature curve.

It was also found that single as well as double TiO-layers occur.

The most striking feature of these compounds is the occurrence of mixed layers polytypes with very long repeat distances in the c-directions.

The $Pb_2Sr_2(Ca,Y)_1Cu_3O_{8+d}$ Family

The proposed structures of these compounds are again related to the perovskite basic structure and can also be considered as being derived from the 1-2-3 structure. The layer sequence along the c-direction can be written as:

$$Y\text{-}CuO_2\text{-}SrO\text{-}PbO\text{-}CuO_\delta\text{-}PbO\text{-}SrO\text{-}CuO_2$$

compared with the layer sequences in the 1-2-3 compound

$$Y\text{-}CuO_2\text{-}BaO\text{-}CuO_{1-\delta}\text{-}BaO\text{-}CuO_2$$

it is clear that the CuO layer is replaced by a triplet of layers PbO-CuO-PbO.

From a preliminary electron diffraction and high resolution electron microscope study, it could be concluded that this structure is probably only a first approximation since the presence of weak superstructure spots is in disagreement with the proposed c-centered unit cell. The superstructure is tentatively attributed to the cooperative tilting of interconnected CuO_δ pyramids.

Notes

TRANSMISSION ELECTRON MICROSCOPY INVESTIGATION OF A BiCaSrCuO THIN FILM.

C. Træholt,
Laboratory of Applied Physics, Technical University of Denmark,
Dk-2800 Lyngby, Denmark.

A thin film of BiCaSrCuO was sputtered onto a single crystal MgO substrate. During the following annealing process, the film cracked along the edge of the substrate, i.e., the film-substrate adhesion seemed to be rather low. The film was observed to have a critical temperature $T_C \equiv 80K$. The thin film was investigated and characterized in a high resolution electron microscope. This was done with the so-called cross-section technique which permits one to get an edge on view of the substrate-thin film interface. The investigation also included an energy dispersive analysis of x-rays from the interface region.

Notes

ELECTRONIC STRUCTURE OF TWIN BOUNDARIES IN $YBa_2Cu_3O_7$ CRYSTALS.

D. Agassi,
Naval Surface Warfare Center, White Oak Laboratory,
Silver Spring, MD.

The electronic structure of a twin boundary (TB) in a $YBa_2Cu_3O_7$ crystal is evaluated from *ab-initio* band structure calculations. Two models are considered. The first one assumes an ideal TB atomic configuration, i.e., the a and b axis interchange across the TB plane. The second model assumes the atomic configuration of the first model modified, however, by oxygen atoms disorder. Specifically, the oxygen atoms are assumed to relocate randomly to vacant lattice sites such that the Cu-O bond length is preserved. For the ideal TM model, we find no conduction along the TB plane except at the intersection of the Cu-O and TB planes. Conductivity in this direction is not intrinsic to the TB. Also, the TB presence introduces TB-attached localized states near E_F which tend to form a quasi continuum. For the disordered TB model, some of the TB-attached localized states broaden into E_F-crossing bands. In the framework of our super-cell modeling, these bands represent conducting pathways parallel to the TB which are comprised of zig-zag shaped Cu-O chains. Implications of the physical picture are briefly discussed.

Notes

SYNTHESIS AND STRUCTURE/PROPERTY RELATIONSHIPS IN HIGH T_c COPPER OXIDES.

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A brief survey of composition and structures of high temperature copper oxide superconductors containing thallium, bismuth, and lead will be presented. An interesting common structural feature is that the part of the structure between nonconsecutive CuO_2 sheets is ill-defined.

Possible correlations of T_c with the structure, bonding, and charge carrier concentration will be discussed. Nonstoichiometry and the existence of extended defects in connection with the Cu^{2+}/Cu^{3+} ratio (hole concentration) in these cuprates will also be discussed.

Notes

NATURE OF CARRIERS IN THE HIGH T_c OXIDES AND RELEVANT PAIRING MECHANISMS.

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We will discuss some of the electronic properties of the high T_c oxides, particularly the important spectroscopic results to establish that the carriers are holes in the oxygen band wherever the material is a p-type superconductor. We will point out that this fact eliminates a number of current pairing scenarios. We will examine, in some detail, the nature of charge transfer excitations in these systems and show their importance to oxygen hole pairing in the high T_c superconductors.

Notes

OXYGEN STOICHIOMETRY, STRUCTURAL TRANSITIONS, AND THERMODYNAMIC BEHAVIOR OF THE $YBa_2Cu_3O_x$ SYSTEM.

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Electromotive force (emf) measurements of oxygen fugacities as a function of oxygen stoichiometry in the $YBa_2Cu_3O_x$ system (1-2-3 superconductor) have been carried out over the composition range $x \cong 6.15$ to 6.9 and the temperature range 400-750°C. A coulometric titration technique with an yttria-doped zirconia electrolyte was used for these measurements. By means of this technique, the oxygen content of the superconductor is varied by well-defined small amounts and the equilibrium oxygen partial pressures can be established from the emf measurements. The overall objective of these studies is to investigate the phase transformations and thermodynamic behavior of the $YBa_2Cu_3O_x$ system as a function of oxygen partial pressure, oxygen stoichiometry and temperature.

In plots of log pO_2 versus x in the temperature range 550-750°C, there was no apparent sign of a change in curvature or discontinuity at an oxygen stoichiometry of $x \sim 6.5$ where copper is divalent and where the orthorhombic-tetragonal transition had been assumed to occur. Of particular importance are reflections around $x = 6.65$ at temperatures between 400 and 500°C. These low-temperature data are consistent with the presence of miscibility gap, as predicted in several theoretical papers, in which two immiscible orthorhombic structures are present having different oxygen stoichiometries. Extrapolation of the data to lower temperatures indicated that an orthorhombic-orthorhombic miscibility gap lies below a critical temperature of $\sim 200^{\circ} \pm 50^{\circ}$C at $x = 6.65$; for the terminal compositions extending between $x = 6.55$ and 6.75, we estimated a temperature of ~ 35°C. Knowledge of the presence and extent of such a miscibility gap is important for optimal preparation of superconducting materials.

A thermodynamic assessment and inter-comparison of our oxygen partial pressure measurements with the results of other measurements will be presented.

Notes

THE SYMMETRIES AND HIGH CRITICAL TEMPERATURE SUPERCONDUCTIVITY.

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We propose that a relation exists between symmetries of the first coordination sphere of copper and/or other valency-changing elements and high T_c superconductivity. The origin of the superconductivity in perovskite-type materials is attributed in part to a three-dimensional nesting of the Fermi surface with the boundary of Jones'-zone, causing ``partially-gapped'' Fermi surface. The pairing mechanisms is exciton-mediated, in which the extreme metastability, constructed by the special coordination symmetry has central role. A gliding charge density wave arises from a three-dimensional ``breathing'' of distorted perovskite structures associated with mixed-valence metal and close-packed seeking symmetry. The experimental evidences are collected to support these ideas.

Notes

OXYGEN EVOLUTION IN HIGH T_c SUPERCONDUCTORS.

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J.-P. Locquet,
IBM Research Division, Zürich Research Laboratory, 8803 Rüschlikon, Switzerland;
and I. K. Schuller,
Physics Department, B019, University of California, San Diego, CA.

We have performed extensive gas evolution, x-ray diffraction and superconducting measurements on a series of high temperature ceramics as a function of oxygen and metal ion composition. In $YBa_2 Cu_3 O_{7-\delta}$, the oxygen evolution kinetics at fixed temperature (400^oC) and vacuum ($P \cong 10^{-6}$ Toor) for varying lengths of time, is found to proceed by an initial large change in "chain" occupancy and a subsequent leveling off. The critical temperature obtained from susceptibility measurements drops from 90K to 60K when the oxygen content in the "chain" decreases. Longer annealing yields a decrease of the 60K superconducting fraction, probably due to oxygen disordering effects since the oxygen content stays constant. Oxygen ordering is investigated using electron microscopy.

Substituting Y with Pr or Na or Y/Ba with La/Ca affects the superconductivity and, except for the Pr case, also influences the oxygen evolution behavior.

Notes

MAGNETIC PROPERTIES OF THE HIGH TEMPERATURE SUPERCONDUCTORS.

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The fundamentals of paramagnetism, ferromagnetism, and antiferromagnetism and evidence of these in the high temperature superconducting oxides and related structures will be reviewed. The Ginzburg-Landau theory will be introduced and used to discuss the critical fields H_c, H_{c1} and H_{c2}, the magnetization M, and the anisotropy of H_{c1}, H_{c2} and M. Elementary ideas of vortex motion, flux pinning, and the critical-current density J_c versus applied field H and temperature T will be described. The kinds of inhomogeneities that are expected to produce large values of J_c versus applied force H and temperature T will be described. The kinds of inhomogeneities that are expected to produce large values of J_c will be discussed. The importance of granularity in the high temperature superconductors will be stressed and the difference between intra-granular and intergranular vortices will be emphasized. The weak-link problem, the inability of grain boundaries in the high temperature superconductors to transmit high current without electrical resistance, will be described. The role of thermal activation and sample inhomogeneities in producing rounding of the nonlinear E (electric field) versus J (current density) curves in conventional and high temperature superconductors will be discussed. The origin of the phenomenon of flux creep will be discussed and related to the rounding of the E versus J characteristics.

Notes

MAGNETIC FIELD PATTERNS IN $Y_1Ba_2Cu_3O_7$.

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A magneto-optic technique using cerium metaphosphate glass at 4.2k has been used to study magnetic field patterns in $Y_1Ba_2Cu_3O_7$ ceramics and samples containing a few large aligned crystals. Studies have been carried out in magnetic fields up to 5 Tesla. Disk, cylinders and stick-shaped samples were studied. We have observed flux exclusion, trapped flux, flux gradients, and the effect of a 100 μm crack. The experiments clearly demonstrate the magnetic field at which flux enters the grains of the superconductor and is subsequently trapped. For comparison purposes, magnetic field patterns in Nb_3Sn and NbTi samples are presented. We also plan to present flux patterns from large single crystal of $Y_1Ba_2Cu_3O_7$.

Notes

MICROSTRUCTURE PROPERTY RELATIONSHIPS FOR HIGH T_C SUPERCONDUCTORS.

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The microstructure of high T_C superconductors is expected to control the physical, mechanical as well as superconducting properties. Of the several related families of high T_C superconducting materials, prepared in thin film, single crystal and polycrystalline form, as expected, T_C is primarily dependent upon crystal and electronic structure. It does not depend too strongly on micro-structure, except for the role of point defects which, for example, control the processing of $Y_1Ba_2Cu_3O_{7-\delta}$ superconductors. However, microstructure is of prime importance in determining the critical current densities and mechanical properties. Apart from point defects, other microstructures in these materials include grain boundaries, dislocations, voids, twins, microcracks, and grain boundary phases. In this paper, we address several microstructure related aspects of high T_C superconductors and their role in determining superconducting properties. Specifically, we consider the role of point defects in determining T_C and the role of grain boundaries and twins in determining J_C

Notes

THE GROWTH OF LARGE SINGLE CRYSTALS, TEXTURED MATERIALS AND THE ELECTROMAGNETIC SHIELDING EFFECTIVENESS OF HIGH T_C SUPERCONDUCTORS.

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The understanding of the basic properties of the new class of high temperature superconductors and the development of technological applications using them are both severely restricted at present by materials problems. On the one hand, large high quality single crystals are needed, while on the other hand, it is vitally important to improve the current carrying capacity of sintered material and to establish the effects of the granular structure on the electromagnetic properties.

In our work directed towards improved materials, we have recently developed an alternative flux-growth technique capable of producing single crystals with volumes > 100 mm^3. These crystals are superconducting as grown, but benefit from oxygen annealing. The growth and properties of these crystals will be discussed along with the effects of processing conditions on the final quality. Particular attention will be given to the relationships which exist between the optical and electron microscope microstructures and between these microstructures and the superconducting properties.

A technique based on CuO-$BaCuO_2$ flux growth methodology has also been used to produce highly textured samples with controllable grain size. The texturing is confined to a 0.1 mm thick surface layer through which a critical current density of 5000 Acm^{-2} can be passed. Pole figure analysis shows that the c-axis alignment is to better than $\pm 1^o$, although there is no ordering of the crystalline orientation in the a-b plane. The preparation and behavior of these textured materials will be considered.

Finally, one application of sintered materials which is generally considered likely to be achieved in the short term is that for electromagnetic shielding.
In order to establish the effects of granularity on this simple application, we have recently carried out a detailed investigation of the shielding effectiveness of both yttrium and bismuth cuprates. The results show that while the shielding is good at low signal strengths, its effectiveness decreases with increasing signal strength. The presence of small static magnetic fields also reduces the performance and importantly there is a memory effect associated with this degradation. The origins of these effects will be considered.

Notes

THE CRITICAL CURRENT PROBLEM IN HIGH TEMPERATURE SUPERCONDUCTORS

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Although the discovery of high critical temperatures in superconductors has broken some conceptual barriers in physics and has raised hopes of immense possibilities in terms of applications, the low critical current densitites usually obtained in bulk polycrystalline superconductors have been a major problem. The reasons for such restrictions are discussed in terms of grain-boundary effects, flux pinning, flux creep, and anisotropy of the superconducting properties. The interplay between fracture toughness and critical current density via grain size of the material is pointed out. Possible solutions to the critical-current problem are identified and discussed. It is indicated that although short samples of thin films may have high critical densities and may be suitable for microelectronics applications, anisotropy of the critical current may preclude application of conductors based on such thin films from large scale applications. For the latter, novel engineering designs may be necessary.

Notes

CRITICAL CURRENT DENSITY DETERMINATION FOR AC SUSCEPTIBILITY AND DC MEASUREMENTS OF YBaCuO SUPERCONDUCTORS.

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Several sintered 123 YBaCuO samples have been prepared with different sintering and annealing conditions. The influence of these treatments on the intergranular critical current density, hysteresis loop and Meissner effect has been analyzed.

The AC-susceptibility has been measured from 4K to above T_c and several applied fields between 8 and 8,000 A/m. Using these data, the intergranular critical current density as a function of temperature has been calculated following a method based on Kim's critical state model. DC-hysteresis loop and Meissner effect at 77K have also been measured.

Possible correlations between our calculated intergranular critical current density and the processing parameters will also be analyzed.

Notes

EFFECTS OF GRAIN BOUNDARY CHEMISTRY ON CRITICAL CURRENT DENSITY IN OXIDE SUPER-CONDUCTORS.

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Grain boundary chemistry has been studied in oxide superconductors using analytical electron microscopy and Auger electron spectroscopy of fracture surfaces. It has been found that grain boundaries in carefully prepared sintered $YBa_2Cu_3O_7$ do not contain detectable concentrations of impurities. However, grain boundaries do tend to be copper-rich and oxygen-poor compared to the bulk. That this non-stoichiometry at grain boundaries may be significant with respect to the weak link problem is suggested by the further observation that small deviations from the stoichiometric composition can have large effects on grain boundary composition, critical current density, and normal state resistivity. The effects on grain boundary chemistry and superconducting properties of small additions of silver, rapid quenching to retain the tetragonal structure and subsequent low temperature oxidation, and heat treatments under elevated oxygen pressures have also been investigated.

Notes

MANIPULATION OF MATERIALS AND PROCESS VARIABLES.

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Superconducting objects are made either from powder or precursors. Powder may be prepared by a solid-state reaction or by reactions from the liquid or gaseous phases. Most gaseous and liquid phase reactions include a final solid-state reaction because the oxide is generally not produced directly from the liquid or gas. The powder may then be dispersed in a vehicle with a binder and plastizier. Pellets, bars, and other simple shapes are formed by dry pressing, long pieces by extrusion, thin sheets by tape casting, and complex shapes by slip casting or injection molding. Swaging, hot extension, and sinter forging can promote texturing or preferential alignment of grains Alternatively, material can be textured when formed directly from the liquid in the presence of a large thermal gradient. Substrates may be coated by screen printing or other painting processes. Densification of green formed shapes is accomplished by heat with or without the aid of mechanical stress. Surface free energy provides the driving force for sintering. Surface energy may be decreased by volume diffusion, grain boundary diffusion, liquid phase diffusion, surface diffusion, and gaseous diffusion. The last two mechanisms do not lead to densification. Thin films of superconducting material can be formed directly from vapor species. The method is usually classified by the method used to form the vapor. Sputtering involves vaporizing a target with an energetic beam of heavy particles. Evaporation usually involves radiant heat or an electron beam. Chemical vapor decomposition (CVD) usually involves a volatile chemical precursor, and may be the method most easily scaled to bulk forms. Fracture of brittle materials is best represented statistically. The strength of a material depends on flaw size and fracture toughness. The distribution of flaws is somewhat random. Generally, strength decreases with increasing size because the probability of a large flaw increases. Strength is improved by limiting the size of the largest flaws and by increasing the fracture toughness. A second phase may be beneficial in relieving stress and arresting cracks. Electrical properties, especially critical current density, depend strongly on the microstructure. In preferentially oriented or textured material, the anisotropy of the crystalline structure may serve to enhance J_c in the desired direction. Second phase may pin flux and prevent losses resulting from flux creep. Excessive and continuous non-superconducting second phase may interrupt the current paths, resulting in so-called weak-link behavior.

Notes

SILVER DOPED YBaCuO THIN FILMS PREPARED BY SEQUENTIAL EVAPORATION OF CuOx/Y_2O_3/BaF_2/Ag.

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We report the fabrication and electrical characterization of polycrystalline thin films of $YBa_2Cu_3O_{7-x}$: Ag. Samples were prepared by sequential evaporation of CuOx/Y_2O_3/BaF_2/Ag onto yttria stabilized zirconia (YSZ) substrates, followed by annealling in O_2 atmosphere. All the samples presented a superconducting transition with $T_c^{onset} \approx 92K$ and $T_c^{(0)} = 84\text{-}86K$. Very low silver concentration (0.5 to 1 vol %) enhances the critical current J_c at 77K by a factor 10 in relation to our undoped samples. A sample with 2 vol % of silver showed semiconducting behaviour above T_c and was not fully superconducting at 77K. Exposure to moisture turned all the samples semiconducting, but left a superconducting onset at around 90K. EDX analysis proved that the silver is located in the grain interfaces. The doped samples can be very useful for device and microwave applications.

Notes

OXYGEN AND ION DOPING IN $Bi_2Sr_2CaCu_2O_{8+\delta}$ SINGLE CRYSTALS.

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Problems with homogeneity and phase segregation have plagued attempts to study carrier concentration dependence of the superconducting and normal state properties in the cuprate high temperature superconductors. An ideal system for this study would be one in which large single crystals can be grown, enabling the un-ambiguous examination of anisotropic properties, and one in which the carrier concentration and superconducting transition temperature can be controlled over a wide range without problems associated with homogeneity or phase segregation.

We describe a directional freezing approach for the growth of large (> 3 cm^2 faces) single crystals in the $Bi_2Sr_2CaCu_2O_{8+\delta}$ system. Ion doping with La(+3) for Sr(+2) and Y(+3) for Ca(+2) as well as oxygen doping has been explored in this system. Oxygen doping allows for a range of superconducting transition temperatures from 90K (Ar annealed) to 77K (oxygen pressure annealed) without transition width broadening or low temperature Meissner signal degradation as the material is doped. Contrary to the $YBa_2Cu_3O_{7-\delta}$ system, increased oxygen content leads to a decrease in superconducting transition temperature. Magnetic, transport, structural, and thermal analysis will be presented for a series of oxygen and ion doped crystals.

Notes

SUPERCONDUCTIVITY BY QUANTUM SIZE EFFECT.

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In sufficiently small metallic particles, the average energy gap between the electronic states due to space quantization can become larger than the thermal energy and then the system condenses quickly into a highly coherent ground-state. The same is true for a system made up of an arbitrarily large number of identical such particles which are insufficiently weak electrical contact such that the broadening of the particle states by the inter-particle interactions remains smaller than the original average energy gap (e.g., by contacts across small metallic bridges or thin tunneling barrier made of insulating material).
The average gap is the larger, the lower the dimensionality of the electron gas (the flatter the Fermi surface). Elastic defect scattering merely reduces the average energy gap. We show that a current can run across such a system in the groundstate, i.e., without relaxation, if the vector potential of the magnetic field of the current is included in the Hamiltonian. If the system is larger than the London penetration depth, there is flux quantization (trapping), a Josephson coupling energy and a large energy barrier against relaxation by electron-phonon scattering (inelastic transitions). We discuss the experimental evidence which is in favor of such a mechanism for the high temperature superconductors.

Notes

BASIC RESEARCH AT HOECHST-REVIEW.

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The presentation will cover the following research activities:
- X-ray and neutron scattering experiments
- XPS and HRTEM measurements
- constitution investigations.

Application related research will cover the following topics:
- power synthesis
- development of ceramics by sintering
- thick film processes like plasma spraying technique
- thin film activities concerning sputtering and IBAD technique.

Notes

A SOLID STATE MODEL FOR THE PROCESSING OF $YBa_2Cu_3O_7$ HTS CERAMIC POWDERS.

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A behavior model is presented based on supporting research, theoretical micro-structural analyses and a literature review. This model integrates the chemical, phase relations, and the micro-twin strain-field transformation behavior. Application of the model to powder and medium and high density compacts will be discussed. Response to explosive compaction will be discussed as an example of workings of the model as well as "regular" sintering behavior.

Current processing protocols vary widely, but most yield similar results which are not adequate for real application. Top HTS quality seems to be achieved only in small batches. The quality of large batches (> 0.2 kg) seems to be uniformly poor, regardless of source. A poor quality of powder causes problems the most advanced sophisticated fabrication process can not overcome.

The model presented here explains the processing results achieved with the variety of protocols. In addition, the model suggests a straight forward integrated approach to achieve improved quality HTS powders and products. Application of this Los Alamos model locally has led to significant improvements in part size and HTS properties.

Notes

MID-INFRARED REFLECTIVITY OF SINGLE CRYSTAL $YBa_2Cu_3O_7$ AND RELATED COMPOUNDS.

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Princeton University, Princeton, NJ; and J. M. Terascon and P. Barboux, Bell Communications Research, Red Bank, NJ.

We have measured room temperature reflectivity of single crystals of the high T_c oxide $YBa_2Cu_3O_7$ (1:2:3) and other related crystals ($Bi_2Sr_2CuO_{6+y}$ and $Nd_{2-x}Ce_xCu_2O_{4-y}$). The reflectivity of the highly conducting 1:2:3 samples (T_c > 91K, pab = 150 μΩ cm at 290K) shows good agreement among samples and is found to be higher than in previous reports. The results are analyzed ellipso-metrically with oblique and near normal incidence data and also using the Kramers-Kronig relations. The parameters obtained from the reflectivity will be compared with DC transport values.

The reflectivity of $YBa_2Cu_3O_7$ and $Bi_2Sr_2CuO_{6+y}$ differs significantly from a Drude model and can be roughly approximated by a sum of a Drude term and a very broad Loentzian. On the other hand, the superconducting, or nearly superconducting, crystals of $Nd_{2-x}Ce_xCu_2O_{4-y}$ shows a very high reflectivity (85-88% at 200 cm^{-1}) which is much closer to Drude behavior.

The nature of reflectivity of $YBa_2Cu_3O_7$ and the other crystals will be discussed as well as the implications of our understanding of the normal state electron dynamics. The reflectivity of $Bi_2Sr_2CoO_{6+y}$ and $Bi_2M_3Co_2O_{8+y}$ (M = Ca,Sr,Ba) which shows clear dependence of the plasma frequency on cation substitution will also be presented.

Notes

THIN FILM GROWTH, PROXIMITY-EFFECT AND TUNNELING IN HIGH TEMPERATURE SUPERCONDUCTORS.

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Superconductivity tunneling and proximity-effect studies have been important probes for understanding basic mechanisms of superconductivity. Historically, thin films have provided the most reliable medium for such studies. Therefore, a short overview of thin-film growth techniques as they relate to the oxide superconductors will be presented. Sputter-deposition, e-beam/thermal evaporation and laser deposition will be compared. The importance of proper characterization, including the use of techniques such as x-ray diffraction, Rutherford Backscattering (RBS), electron microscopy and optical techniques (e.g., Raman), will be reviewed. A definition of the proximity-effect will follow, with examples involving conventional and non-conventional (e.g., heavy fermion) metals and superconductors. The concept of single-particle and Josephson tunneling will then be presented. Examples of superconductor-insulator-superconductor (SIS) and superconductor-normal metal-superconductor (SNS) junctions involving conventional superconductors, depicting what information can be derived from studying such structures, will be detailed. Throughout discussions of these artificially-layered structures, the importance of having well-characterized materials will be stressed together with the criteria used for determining the quality of proximity layers and junctions. The goal here is for the audience to be left with some ability to decipher reliable vs unreliable data in the literature and in their own laboratories. Due to the inherently short coherence lengths in the high temperature superconductors and the non-superconducting nature of the surface (the later being either intrinsic or materials-related), there is great difficulty in producing reliable junctions. Several results of proximity-effect studies and tunnel junctions involving the high temperature superconductors will close the lecture.

Notes

DEVELOPMENT OF HIGH T_c SUPERCONDUCTOR WIRES.

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Possible future application of the ceramic high T_c superconductors (HTSC) in magnet and energy technology makes necessary the development of conductors with both high critical current density and high critical current. As for the metallic superconductors, composites have to be developed in form of multi-filamentary wires or sandwiched tapes consisting of the superconducting material, an electrical stabilizer and a reinforcing member. As a first step, the current carrying potential of HTSC bulk material and wires is presently being explored, mainly for the systems YBaCuO and BiSrCaCuO. The predominant features encountered are the weak link behavior of grain boundaries and flux creep effects at temperatures much above 4.2K. The weak link behavior can be reduced largely by melt processing and texturing leading to relatively high critical current densities in YBaCuO even at 77K. In BiSrCaCuO, the current carrying capacity is low due to flux creep down to temperatures of about 20K. These effects are discussed more in detail on the basis of measurements performed on $Y_1Ba_2Cu_3O_7/Ag$ and $Bi_2Sr_2Ca_1Cu_2O_8/Ag$ wires produced by the powder-in-tube method. Due to the lower processing temperatures of the Bi-compound melt processed wires exhibiting record values of $1.5 \cdot 10^4$ A/cm^2 at 4.2K in 26T external field could be achieved.

Notes

SYNTHESIS OF HIGH TEMPERATURE SUPERCONDUCTOR WIRES VIA PLASTIC DEFORMATION.

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Efforts at the Naval Surface Warfare Center for the past year have been focused on the development of processes which can lead to technologically adaptable methods for synthesis of wire tapes or foils. Several approaches, including rapid solidification, reaction synthesis, and thermal decomposition coupled with plastic deformation, have been examined. The most promising of these three methods consists of silver nitrate decomposition possibly according to equation: $AgNO3 \longrightarrow Ag + NO3 + O2$ at 500°C to deposit pure Ag on the HBCO ($YBa_2Cu_3O_{7-x}$) powder mass. The composite powder thus obtained is then compacted and converted to wire/rod configuration via swaging through conical converging dies at room temperature and elevated temperatures. Samples containing up to 25 wt % Ag exhibit zero resistance at 93K. The J_c values were very low initially but have steadily increased to 200 A/cm^2. The present target value for J_c is 1,000 A/cm2 which may be reached with optimization of powder particle size and distribution, grain orientation, Ag concentration, and annealing procedures. All three processing methods will be described with major emphasis on $AgNO_3$ derived wires accompanied by SEM, XPS and Auger analysis. Electrical properties (T_c and J_c) and measurement procedures will be presented in detail.

Notes

AMORPHOUS METALLIC PRECURSORS BY HIGH ENERGY BALL-MILLING FOR HIGH T_C SUPERCONDUCTORS.

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Amorphous metallic precursors can be used as starting materials for the fabrication of high T_C superconductors. We have looked at this particular process since crystallization of the amorphous metallic powders during oxidation at high temperatures may result in some kind of texturing phenomena. We present results of the amorphization process of metallic powders using high energy ball milling by x-ray diffraction analysis, differential scanning calorimetry and thermal gravimetric analysis to determine their crystallization temperatures as well as their oxidation characteristics. Magnetic and transport properties (J_C, H_C, etc) on superconducting consolidated samples as well as sheathed silver wires containing the superconducting powders will be discussed. Finally, microstructural investigation will be made using SEM and Auger microscopy.

Notes

SUPERCONDUCTIVITY IN MEDICINE.

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The applications of superconductivity were restricted to basic research and high energy physics laboratories for a long time, although there has been a world wide effort to demonstrate industrial realizations in the area of energy generation, conversion, distribution, transportation, and ultra-fast logical circuits. Small bore S.C. homogeneous magnets from 6T to 15T have been successfully introduced into chemical laboratories for molecular structural analysis by NMR spectroscopy. The breakthrough into everyday life came with the development of whole body MR imagers in 1980 which brought superconductivity into a general hospital and even into the radiologist's consulting room. There is now a 600 unit per year market equivalent to about one billion dollars.

MRI yields high resolution images of the human body with high contrast between healthy and tumorous or inflamed biological tissues. It utilizes solely magnetic fields: a strong static homogeneous main field for polarizing the nuclear magnetization of the water protons, gradient fields for spatial resolution, and radio frequency fields for excitation and signal reception. The basic principles of MRI will be discussed. The chief component of an imager is the main field magnet. In the dominant medium and high performance market segments, this is a S.C. six-coil design with 1m warm bore with field strengths from 0.5T up to 4T. Reduction of the hospital area, contaminated by their strong stray fields, has pushed the acceptance of this new diagnostic modality. Dedicated cooling strategies (evaporation of LHe + LN_2; active cooling of the radiation shields; closed cycle refrigeration) help adapt the cryogenic system to local resources. Increasing magnetic field quality has allowed sophisticated new imaging variants, like high resolution 3-*D* imaging of the joints, angiography of blood vessels, snapshot images of the heart, and localized *in-vivo* spectroscopy.

The nerve currents of the human heart produce weak magnetic fields of the order of 20pT outside the body which already in the early 1960s could be detected by simple pick up coils (magnetocardiography, MCG). The use of a SQUID sensor has allowed us to measure also weaker magnetic fields of the brain currents (≈ 100 ft, magnetoencephalography, MEG). However, a global temporal signal is much easier to attain by measuring the electric potentials at the skin; thus ECG and EEG today are common medical practice. The main advantage of MEG is the novel possibility of locating the current source of the magnetic effect, so one can find an epileptic center or the region of evoked brain activity due to a controlled applied optical or acoustical stimulus. For this purpose, the spatial distribution of B must be measured near the head's surface. As tissue is magnetically inert, the strength and the locus of a small current dipole may be fitted to the field map. Because of the time dependence of the effects, the map data must be collected simultaneously which leads to the necessity of a multichannel SQUID arrangement. Siemens has developed a 30 channel system built up from 10 SQUIDs chips. Each SQUID is driven in the flux locked loop mode. Axial first order gradient pick up coils reduce interference with the magnetic background noise, thus allowing a medium magnetic shielding factor (> 1,000) of the examination room. Technical details and first results will be shown.

Notes

THE DEPOSITION OF SUPERCONDUCTING CERAMICS.

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A materials science overview of the deposition of ceramic superconductor thin films is presented. The emphasis will be on an assessment of the main issues relating to the production of practical thin films. Besides reference to the extensive literature, some specific examples of results and phenomena of the sputter deposition of these films will be given from our own experience. The deposition of such a complex single crystal film has rarely been achieved in the past by means of vapor phase deposition, so, as part of the initial introduction, a review will be given of the deposition of similar, yet simpler to deposit, oxide systems.

A brief description will be given of the two main routes of thin film production with some of their variants: the in situ route in which the films are made with a perovskite-like structure directly; and the more widespread and less demanding post heat treatment route in which the material is made initially as a micro-crystalline mixture and subsequently heat treated. The critical issues involved in the deposition of these materials, namely, the stoichiometry, epitaxy, substrate choice and oxygen activity during the deposition, will be described in detail. The stoichiometry will be discussed with particular reference to the effects of off-stoichiometry on a growing film. The substrates issue will be discussed in relation to chemical interaction, the use of buffer layers, the growth of single crystal films, and the role of the dielectric constant of the substrate on likely applications. The quality of the epitaxy will be discussed with emphasis on the critical current, the orientation of the desired current flow, and the possibilities of using different orientations besides the standard (100) orientation. The last issue to be highlighted, active oxygen, will be discussed in terms of the means of its production, the possible role it has during the growth, and the results workers have achieved with its use.

A description of the different vapor phase deposition techniques will be given and the capabilities of these different techniques will be assessed in the light of the main deposition issues. Some specific issues relating to these films will be addressed with respect to their use in practical applications. The relation of the critical current to the orientation, structure, and quality of the film will be considered. Finally, a discussion will be initiated on the possibilities for scaled up production of these materials.

Notes

EPITAXIAL THIN FILMS OF $YBa_2Cu_3O_7$.

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Thin films of Y:Ba:Cu:O have been deposited onto $SrTiO_3$ substrates by evaporation from three e-beams in a UHV system. Compositional uniformity is assured by substrate rotation during evaporation. On subsequent annealing, they become epitaxial and superconducting with T_c values up to 85K. The preferred orientation is correlated with the composition.

Film quality has been assessed using a mutual inductance technique, dc magnetization, and by transport measurements on laser defined narrow tracks. The good film uniformity has allowed critical current measurements to be made on long meander tracks, so as to extend the range of electric fields at which measurements are possible. For example, four tracks 55 mm long and 40 μm wide were cut on a single substrate and all were found to have critical current densities in excess of 5×10^5 A/cm^2 at 77K, even with the relatively stringent field criterion of 5 nV/m. Current-voltage characteristics of these tracks are being studied.

Notes

NMR AND NQR OF Cu IN HIGH TEMPERATURE SUPERCONDUCTORS.

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The nuclear resonance spectra of the two Cu isotopes in the high T_c superconductors are complicated by the superposition of magnetic dipolar and electric quadrupolar hyperfine interactions. By combining zero-field spectra (quadrupole and nuclear antiferromagnetic resonance) and field-sweep spectra of oriented powder samples or single crystals, the different interactions in the system $YBa_2Cu_3O_y$ have been analyzed for y = 7 (superconducting) and y = 6 (semi-conducting antiferromagnetic). Mössbauer spectra on ^{57}Fe-doped samples have confirmed these results and have shown the separation of the electric field gradient in lattice and ionic contributions [1]. For y = 6, two different magnetic structures have been found depending on the presence of a small amount of magnetic impurity on the Cu(1) sites. In contrast to results deduced from neutron scattering, no static magnetic moments exist on the Cu(1) sites in both structures.

In the Bi-based superconductors, the Cu signals have been observed by field-sweep and zero-field resonance. A broad distribution of the quadrupole frequencies is found indicating that the Cu sites are non-equivalent in these compounds, most probably due to stacking faults.

[1] Brand, R. A., C. Sauer, H. Lütgemeier, B. Rupp and W. Zinn. Physica C 156:539 (1988).

Notes

EPR AND MICROWAVE ABSORPTION MEASUREMENTS ON SINGLE-CRYSTAL Ti-Ca-Ba-CuO.

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and E. H. Poindexter and G. J. Gerardi,
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EPR and microwave absorption measurements at 9.2 GHz were made on single-crystal Ti-Ca-Ba-CuO material. Fourteen crystals were examined: six 2122 samples, four syntactic crystals, three 2223 polycrystals, and one 2223 sample. A resonant absorption observed at room temperature and characterized by $g = 2.224$ and $g_2 = 2.045$ for the low- and high-field extrema, respectively, was observed from one of the 2122 crystals. The absorption is consistent with that for divalent copper. The absorption showed some line shape anisotropy when the orientation of the crystal c-axis was altered between parallel and perpendicular with respect to the applied Zeeman field. The results are consistent with the model that no EPR absorption attributable to divalent copper is observable from the superconducting planes of this system. The paramagnetic center is thought to originate from an as yet uncharacterized impurity phase. Further, it should be noted that no absorptions attributable to divalent thallium were observed from any of the samples. All the crystals studied showed microwave absorption consistent with the superconducting transition temperature of the material.

Notes

HIGH T_C SUPERCONDUCTORS: POWER APPLICATIONS.

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The feasibility, technical performance and superiority of superconducting plants and systems has already been demonstrated with metallic superconductors (NbTi, Nb_3Sn) by a number of large application oriented demonstration projects. These included high power cables, motors for ship propulsion, turbogenerators, magnets for ore separation, magnets for fusion test facilities, magnetohydrodynamic generator (MHD) prototypes, magnetic energy storage (MES), and magnetically levitated high speed trains (MAGLEV). However, until now the successful introduction of such new components or systems into our power or traffic system has not yet occurred. There may be two or three exceptions within a reasonable space of time, superconducting turbogenerators, MES and levitated trains. An essential reason for the limited usage of superconducting equipment today apparently is the necessity of cooling with liquid helium which is rather complicated and expensive. The appearance of the new high T_C superconductors with their ability of liquid nitrogen cooling has considerably increased the prospects of a wide spread application of superconductivity in magnet and power engineering. Cooling with liquid nitrogen is more effective, reliable, and less expensive than with 1 He.

However, the degree of improvement which can be achieved in comparison with metallic superconductors strongly depends on the portion of the superconducting and cryogenic components of the total installation. Under the assumption that conductors are available which are workable and able to carry current densities of approximately 10^5 A/cm^2 in non-negligible magnetic fields and have comparable prizes (corresponding to metallic superconductors) the following results have been obtained: for turbogenerators, the economical break-even-point will be shifted down into the power range of 200 to 400 MVA extending the potential market remarkably; with respect to AC power cables, economic equality seems to occur between 1,000 and 2,000 MVA/cct, i.e., at power levels which are at the top end of underground power transmission. Simpler construction, lower operational losses also increase the prospects of S.C. transformers and current limiters. The same is true for MES where the investment costs can be brought down about 10% and the efficiency can be enhanced to approximately 93% when operated as diurnal storage and to approximately 90% when working as weekly storage. Noticeable savings in plant and operating costs can be expected for magnetic systems applied to industrial processes. However, the transition to the new superconductors will have less influence on the development of fusion reactors and MHD-generators which is also true for MAGLEV.

Notes

SUPERCONDUCTING PROPERTIES AND IRRADIATION INDUCED EFFECTS OF EPITAXIAL YBaCuO THIN FILMS PREPARED BY LASER EVAPORATION.

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Epitaxial c-axis oriented YBaCuO films with critical current densities J_C up to 5 x 106 A/cm^2 at 77K have been grown *in-situ* on different single crystalline substrates by excimer laser evaporation. The substrate temperature was adjusted between 680°C and 800°C and the oxygen partial pressure during the evaporation was chosen in the range 0.01 mbar to 0.5 mbar. The films were characterized by inductive and resistive T_C measurement and X-ray analysis. For the j_C measurement strip lines of 10μm width were etched with diluted phosphoric acid. J_C has been investigated as a function of the magnetic field direction up to 8T at various temperatures. Defects have been generated in these films by a too low oxygen pressure during the evaporation as well as by irradiation with 25 MeV ^{16}O ions and 173 MeV ^{129}Xe ions. A decrease of T_C in correlation with an extension of the c-axis parameter is observed. A j_C enhancement in magnetic fields above 0.5T occurs for both, O and Xe ion irradiated samples, caused by an additional defect induced flux line pinning. The effects of the irradiation with the two projectiles differ dramatically as revealed by the T_C reduction and the resistivity increase as a function of the irradiation fluence.

Notes

Poster Sessions

WEEK ONE SESSIONS:

1. **CORRELATIONS BETWEEN PREPARATION CONDITIONS, MODULATIONS AND Tc IN SINGLE CRYSTALS AND CERAMICS OF Bi-Sr-Ca-Cu-O SYSTEM.**
   G. Vacquier.

2. **ANISOTROPY OF TRANSPORT AND OPTICAL PROPERTIES OF BiSrCaCuO.**
   I. M. Tsidilkovski.

3. **INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE I-V CURVES OF THE HIGH T_c SUPERCONDUCTOR $YBa_2Cu_3O_{7-\delta}$.**
   L. Kirkup.

4. **RAMAN SCATTERING FROM METAL SUBSTITUTED $YBa_2Cu_3O_{7-\delta}$.**
   M. Kakihana.

5. **PREPARATION AND MAGNETIC STUDIES OF (Bi,Pb)SrCaCuO SUPERCONDUCTORS.**
   R. Job.

6. **PHYSICAL AND CHEMICAL PROPERTIES OF Ti- and Bi-CONTAINING HIGH T_c SUPERCONDUCTING COMPOUNDS.**
   H. P. Fritzer.

7. **SPECIFIC OPERATIONS OF CERAMIC RF-SQUID AND DYNAMICS OF MAGNETIC FLUX VORTICES.**
   V. M. Zakosarenko.

8. **CRITICAL CURRENT AND ELECTRONIC PROPERTIES OF YBaCuO-Ag COMPOUNDS.**
   B. Dwir.

9. **GRAIN CONNECTIVITY AND SUPERCONDUCTIVITY OF BULK HIGH TEMPERATURE SUPERCONDUCTORS.**
   F. M. Costa.

10. **FORMATION OF DIFFERENT PHASES IN $Y_1Sr_4Ca_{4+x}Cu_{6+x}Oz$ SYSTEM.**
    E. Özdas.

11. **RECENT $\mu+$ SR RESULTS ON SUPERCONDUCTIVITY AND MAGNETIC ORDER IN LAYERED HIGH T_c MATERIALS.**
    E. J. Ansaldo.

12. **ATOMIC ORDERING PROCESSES, THE T_c LATTICE PARMETER AND AT% CORRELATIONS FOR Nb_3Sl AND Nb_3Ge AND OPTIMIZATION STRATEGIES FOR HIGH T_c SUPERCONDUCTING FILMS.**
    Ernst L. Haase.

13. **PERSISTENT CURRENTS IN MESOSCOPIC RINGS.**
    E. Zipper.

CORRELATIONS BETWEEN PREPARATION CONDITIONS, MODULATIONS AND Tc IN SINGLE CRYSTALS AND CERAMICS OF Bi-Sr-Ca-Cu-O SYSTEM.

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Samples of nominal composition $Bi_2Sr_3CaCu_2O_{8+d}$ (2212), heated at 880-950°C then slowly cooled (3°/h), get small single crystals. By resistivity measurements, a Tc evolution with annealing temperature from 86K (880°C) to 94K (950°C) has been observed on these crystals.

These same crystals have been characterized by X microanalysis and micro-diffraction. An incommensurate modulation always occurs along b* with different possible q* values. The incommensurate phase with T_c = 94K and standard 2212 composition may be approximately sinusoidal modulation with only one satellite. Other samples, treated on lowest temperature, display a T_c between 93K to 86K, present several harmonic satellites and correspond to composition ratio deviation from 2212.

For understanding the influence of thermal treatment on modulation and T_c, varied processings are made from the same initial batch: annealing to diverse temperatures (880 to 947°C; three or ten days) then air hardening or very slow cooling (1°/h) to 820°C.

X-ray diffraction on these samples clearly shows that 2212 disappears above 900°C when hardening, while this last compound partially reappears during slow cooling.

Resistivity measurements confirm the absence of the superconductive phase ($T_c \equiv 85K$) when hardening above 90°C. Last results on microscopy of these samples will be presented.

After the disappearance of 2212 phase, the major phase corresponds to yellow crystals observed in most growing tests of 2212 by melt-slow solidification. By x-microanalysis, these crystals are without Cu and approximately correspond to $CaSr_2Bi_{2,5}O_x$. Complete characterization of this phase is in progress.

Notes

ANISOTROPY OF TRANSPORT AND OPTICAL PROPERTIES OF BiSrCaCuO.

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We have studied the transport and optical properties of some $Bi_2Sr_2CaCu_2O_8$ single crystals grown from the melt by the spontaneous crystallization method. There will be presented temperature and magnetic field dependencies of resistivity $\rho(T,H)$, Hall coefficients $R_H(T)$ and thermoelectric power $\alpha(T)$ for oriented samples cut in the plane ab and ac. The transition width $\Delta T \cong 10K$, $T_c = 84K$. At $T > 100K$, $\rho(T)$ for both samples is a linear function. The Hall coefficient is always positive and obeys the $R_H \alpha T^{-1}$ law. The Hall mobility $\mu H_2 < I\ cm_2/V.S$. At $T < T_c$, the thermoelectric power equals zero. At $T > T_c$, $\alpha(T)$ rises sharply, reaches a maximum, and decreases linearly reversing the sign from positive to negative. When the IR radiation is reflected at the ab plane of the crystal, the spectrum type is determined by Drude's dispersion relation. For the reflection at the ac plane, the reflection spectra exhibit some features that result from the interaction of the radiation with phonons. We have found an anisotropy of the superconducting gap parameter $2\Delta/T_c$ which is equal to 5 ± 0.5 for $E \perp$ and to 7 ± 0.5 for $E \parallel c$.

Notes

INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE I-V CURVES OF THE HIGH T_C SUPERCONDUCTOR $YBa_2Cu_3O_{7-\delta}$.

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I-V characteristics as a function of temperature were obtained for poly-crystalline samples of the high T_C superconductor $YBa_2Cu_3O_{7-\delta}$. From an analysis of the I-V curves, the variation of the critical current, I_C, with temperature was established down to 70K. By applying the theory of weak links in superconductors to the data, a value for the energy gap in the material at 0K is inferred. This value is compared with those reported by other workers. In addition, the I-V curves are shown to be consistent with the form, $V \alpha (I - Ic)^a$ where a is a temperature dependent exponent. a is found to tend to a value of 1.5 near to the critical temperature. Comparison is made with predicted I-V relationships based on two- and three-dimensional percolation models of high T_C superconductivity.

Notes

RAMAN SCATTERING FROM METAL SUBSTITUTED $YBa_2Cu_3O_{7-\delta}$.

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A systematic Raman scattering study has been performed on a series of $YBa_2Cu_{3-x}M_xO_{7-\delta}$ (M = Co, Ni and Zn) superconductors of different doping concentrations x. We have investigated changes of the oxygen vibrational modes induced by selective substitution of Co on the Cu(1) sites in the CuO chains and of Ni and Zn on the Cu(2) sites in the CuO_2 planes with the intention of studying the role of the two different Cu sites in the structure. The x-ray diffraction data show that the structure transforms from orthorhombic to tetragonal at $x \cong 0.15$ for Co-doped samples, while for Ni- and Zn-doped samples the structure remains orthorhombic throughout the investigated concentration range (up to $x = 0.3$). The observed effects on the Raman spectra for increasing Co-concentration are a marked decrease in the frequency of the O(4) axial stretching vibration, a slight increase in the frequency of the O(2), O(3) in-phase out-of-plane vibration, and an increase in the intensity of the corresponding out-of-phase vibration. The observed changes in the Raman spectra for increasing Co-concentration are reminiscent of those observed for pure $YBa_2Cu_3O_{7-\delta}$ samples of increasing oxygen deficiency. The frequency of the O(4) stretching vibration is observed to be correlated with T_c for both Co-substituted and oxygen deficient $YBa_2Cu_3O_{7-\delta}$. It is suggested that the O(4) stretching vibration is sensitive to small changes of the charge balance between the CuO chains and the CuO_2 planes. In contrast to the Co-doping, the Raman spectra are more or less independent of Ni- and Zn-doping, which suggests that Ni and Zn enters the Cu(2) sites. Moreover, absence of any change of the O(4) axial vibration indicates that the charge balance between the Cu(1) chains and the Cu(2) planes is unaltered.

Notes

PREPARATION AND MAGNETIC STUDIES OF (Bi,Pb)SrCaCuO SUPERCONDUCTORS.

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Single crystalline BiPbSrCaCuO-(2212)-superconductors were prepared from the melt by a Bridgman-Stockbarger procedure. A following heat treatment under oxygen atmosphere has great influence on the superconducting properties of the materials, raising drastically the critical temperature T_c. Magnetic measurements were carried out in dependence on field and temperature with the applied field either parallel to the c-axis or parallel to the a,b-plane of the unit cell. The temperature dependence of the critical field strength H_{cl} was also measured. Moreover, the influence of the Pb substitution for Bi on the structural and magnetic properties of polycrystalline samples prepared by the conventional ceramic technique was investigated. The increase of the Pb content leads to a substantial promotion of the 107K-(2223)-phase.

Notes

PHYSICAL AND CHEMICAL PROPERTIES OF Ti- and Bi-CONTAINING HIGH T_c SUPERCONDUCTING COMPOUNDS.

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In our earlier work on the ceramic HTSC field, we investigated various properties of the $RBa_2Cu_3O_{7-d}$ family with R = rare earths and Ti. Furthermore, the influence of chemical doping with Ag and F was also studied.

The present contribution deals with the synthesis, magnetic susceptibilities, electric transport properties and structural information, respectively, of some representative microcrystalline superconductors in both the Bi- and Ti-families. Furthermore, the effects of chemical doping with Ag, Cd and Pb on some of the compounds are also presented.

Both the single phase and multiphase samples were prepared by different ceramic, quartz tube and standard methods, and analyzed by x-ray powder diffraction, electron microprobe methods and infrared transmission spectra. For thermal history and stability studies, DTA-TG techniques were applied.

Especially the dc-magnetic susceptibility data proved to be a very quick and sensitive check of the quality of the various compounds tested at both different temperatures and medium inducting fields.

As typical examples, a compound with the nominal composition $Ti_2Ba_2Ca_2Cu_{2.6}Ag_{0.4}O_x$ shows a decrease of the SC onset temperature to 112K with zero resistance at 102K, whereas a sample with the nominal composition $Ti_2Ba_2Ca_2Pd_{0.2}Cd_{0.2}Cu_{2.6}O_x$ reveals a smaller decrease of T_c to about 117K.

Notes

SPECIFIC OPERATIONS OF CERAMIC RF-SQUID AND DYNAMICS OF MAGNETIC FLUX VORTICES.

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Single-hole rf-SQUIDs have been investigated. The SQUIDs were made of bulk ceramic pellets with axially drilled holes. The slit connecting the hole with outer space was made in such a manner that a small cross piece (bridge) remained in the slit to close a current circuit around the hole. This bridge, is believed, could serve as a weak link, even though it had macroscopic dimensions. Various modes of SQUID operations could be observed. These modes correspond to well known hysteretic and non-hysteretic modes of conventional (for instance, niobium) rf-SQUIDs. The ceramic SQUID characteristics are different from that of conventional SQUIDs; special thin film niobium SQUIDs modeling the distinctive features of ceramic SQUIDs have been fabricated.

The results indicate that the operations of ceramic SQUIDs are defined by the motion of magnetic flux vortices in the bridge material. The non-hysteretic modes of operations correspond to reversible vortex motion without pinning. In the case of pinning, the critical state arises in the bridge when the induced current reaches the critical value. The critical state is similar to that of the Beam model.

Notes

CRITICAL CURRENT AND ELECTRONIC PROPERTIES OF YBaCuO-Ag COMPOUNDS.

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We present electronic properties (resistivity, critical temperature, critical current) and structural data of $(Y_1Ba_2Cu_3O_{7-\delta})_{1-x}Ag_x$ ceramic compounds. We found that in these samples silver fills the intergranular space ("holes") without substitution, thus making the samples more compact and improving the intergrain contacts. The T_c of the YBaCuO-Ag samples remains at ~ 92K like in the YBaCuO samples. Normal-state resistivity is decreased by up to two orders of magnitude when adding up to 50 wt% Ag (T_c = 87K) and the samples exhibit improved contact resistance, better mechanical properties and resistance to water. We analyzed the percolation properties of these compounds and found that the critical indices t,s arc in agreement with 3D percolation theory, but p_c is higher than expected. The critical current density J_c is enhanced by a factor of 15% to 50%, when ~ 10 wt% Ag is added to YBaCuO ceramics. The maximum of critical current appears simultaneously with maximum YBaCuO compactness in the samples. J_c estimated from magnetization can reach 5×10^4 A/cm2 at T 4.2K. We show preliminary results on electronic properties of 2D YBaCuO thick films which we prepared by the spin-on technique.

Notes

GRAIN CONNECTIVITY AND SUPERCONDUCTIVITY OF BULK HIGH TEMPERATURE SUPERCONDUCTORS.

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and
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The sintered bulk sample of ceramic superconductors were prepared with the nominal composition of $YBa_2Cu_3O_{7-x}$, by promoting solid state reactions between Y_2O_3, $BaCo_3$ and CuO powders. The transport properties of the high temperature superconductor are dependent upon grain boundary phases and the anisotropy grain growth. The among values of connectivity and grain orientation are correlated with electrical properties and the sintering temperature of the ceramic superconductors.

Notes

FORMATION OF DIFFERENT PHASES IN $Bi_4Sr_4Ca_{4+x}Cu_{6+x}O_z$ SYSTEM.

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The formation of different phases in the $Bi_4Sr_4Ca_{4+x}Cu_{6+x}O_z$ with nominal compositions varying between x = 0 and x = 3 were studied by x-ray powder diffraction, resistivity, magnetization and DTA measurements. Glass samples were made by splat-quenching from the melt at 1100°C with a quench rate of about 10^4 $Ksec^{-1}$. Three different phases which have compositions of Bi_2SrCuO_4 (T_c = 10K), $Bi_2Sr_2CaCu_2Oz$ (T_c = 85K) and $Bi_2Sr_2Ca_2Cu_3O_z$ (T_c = 110K) have been observed by resistivity and magnetization measurements depending on partial pressure of oxygen, sintering temperature and time, and the initial calcium and copper content of the samples. The tangled x-ray powder diffraction pattern of co-existing three phases have been completely identified. A phase change cycling has been observed during which 110K phases increase in volume percent with increasing annealing time at 860°C under lower oxygen partial pressure in calcium and copper rich samples. The melting point observed decreased by reduced oxygen partial pressure. The formation of different phase in $Bi_4Sr_4Ca_{4+x}Cu_{6+x}O_z$ system depends upon sample processing, in particular, partial pressure of oxygen and the annealing time and cooling rate.

Notes

RECENT μ+ SR RESULTS ON SUPERCONDUCTIVITY AND MAGNETIC ORDER IN LAYERED HIGH-T_c MATERIALS.*

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Recent Muon spin rotation (μ^+ SR) results, obtained mostly at TRIUMF, on the interplay between superconductivity and magnetic ordering for a variety of high T_c materials and their precursors will be reviewed.

New measurements of the magnetic penetration depth in the Bi-Sr-Ca-Cu-O family will be presented and compared to the existing systematics of T_c vs carrier densities for other one- two- and three-layered materials.

*Work supported by NRC and NSERC of Canada.

Notes

ATOMIC ORDERING PROCESSES, THE T_c, LATTICE PARAMETER AND AT% CORRELATIONS FOR Nb_3Si AND Nb_3Ge AND OPTIMIZATION STRATEGIES FOR HIGH T_c SUPERCONDUCTING FILMS.

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Thin films of Nb_3Ge and Nb_3Si showed lack of reproducibility in T_c, as do many samples of the high T_c materials. The lattice parameter a_o values also varied by as much as 1%. After clarification of the causes of the discrepancies, unique linear correlations are presented between T_c, ao and at%, which permit an ordering of the literature data. The very limited number of homogeneous samples are nearly perfectly ordered and have, like V_3Si and Nb_3Sn, the same minimally possible, stoichiometrically dependent specific resistance. Stochiometric A15, as well as probably the refractory B1, materials have a specific resistance of 2.2 $\mu\Omega$cm. Nearly all others layers are inhomogeneous, including the epitaxial films. For some samples, at a detection limit of 0.02 at% O, no oxygen is present in the A15 phase, although about $2x10^{-6}$ Torr oxygen was present during the coevaporation. This is also evidence for the atomic ordering processes. Based on very limited data. T_c a_o and at% correlations are proposed for Nb_3Si, in analogy to Nb_3Ge. The linear extrapolations to stoichiometric composition yield a T_c of about 26K and a_o =0.5077 nm. The study of past optimum preparation conditions and their application to the high T_c materials has lead us to new optimization strategies. The $YBa_2Cu_3O_7$ system has, in our experience, many more relevant optimization parameters and, to our knowledge, perfectly ordered epitaxial films with both a-b and c orientation have not been prepared as yet. With up to 10 to 15 relevant parameters, and even only 3 tries for each, there are up to about 3^{12} or 500,000 possible combinations. Therefore the strategies must be carefully planned. To reach rapid success internationally, even partially successful strategies should be disclosed.

Notes

PERSISTENT CURRENTS IN MESOSCOPIC RINGS.

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Persistent currents in mesoscopic rings threaded by a magnetic field are studied. Due to mesoscopic dimensions, the system has a discrete energy spectrum and the level spacing at the fermi surface is large, compared with the thermal excitations at sufficiently low temperatures. The inclusion of selfinductance of the ring gives the selfconsistent equation for the flux and leads to the flux trapping.

The formulas for the susceptibility and persistent current are derived. The flux quantization and the dependence of the transition tempertature on the selfinductance of the ring are discussed.

Notes

WEEK TWO SESSIONS:

1. **YBaCuO THIN FILMS PREPARED BY ORGANOMETALLIC AEROSOL DEPOSITION.**
   Q. Tang.

2. **THERMOELECTRIC POWER IN SUPERCONDUCTING CERAMIC OXIDES.**
   E. B. Lopes.

3. **MICROWAVE PROPERTIES OF HIGH T_c MICROBRIDGES.**
   B. B. G. Klopman.

4. **PREPARATION OF Bi-Sr-Ca-Cu-O SUPERCONDUCTOR PHASES: GLASS CRYSTALLIZATION VERSUS SINTERIZATION METHOD.**
   A. P. Gonçalves.

5. **ELASTIC AND ANELASTIC EFFECTS IN $GdBa_2Cu_3O_{7-\delta}$ AS A FUNCTION OF PRESSURE AND TEMPERATURE.**
   M. Cankurtaran.

6. **EFFECTS OF OXYGEN STOICHIOMETRY ON SUPERCONDUCTING PROPERTIES OF THE CERAMICS $ABa_2Cu_3O_{7-\delta}$ WITH A = Yb,Y,Gd AND La.**
   M. Buchgeister.

7. **MICROWAVE SURFACE IMPEDANCE MEASUREMENTS IN HIGH Tc MICROSTRIP TRANSMISSION LINES.**
   S. M. Anlage.

8. **PREPARATION OF $YBa_2Cu_3O_{7-\delta}$ BY SPRAY DRYING METHODS.**
   H. Vlaeminck.

9. **HYSTERESIS OF CRITICAL CURRENTS IN $YBa_2Cu_3O_{7-x}$.**
   S. Zannella.

10. **THE EFFECT OF PROCESSING PARAMETERS ON THE CHARATERISTICS OF $YBa_2CU_3O_y$ SUPERCONDUCTORS.**
    M. Özenbas.

11. **FORMATION AND CHARACTERIZATION OF $YBa_2Cu_3O_y$ SUPERCONDUCTOR THIN FILMS PREPARED BY SPUTTERING.**
    M. Özenbas.

12. **EFFECT OF FAST NEUTRON IRRADIATION DAMAGE OF 110 K PHASE OF Bi-Pb-Sr-Ca-Cu-O SYSTEM**
    P. Przyslupski.

13. **SUPERCONDUCTIVITY IN MULTIPHASE Bi-Sr-Ca-Cu-O THIN FILMS DEPOSITED BY SINGLE RESISTIVE EVAPORATION SOURCE.**
    J. Azoulay.

14. **LOCALISATION EFFECTS IN RADIATION DISORDERED HTSC.**
    V. I. Bobrovskii.

YBaCuO THIN FILMS PREPARED BY ORGANOMETALLIC AEROSOL DEPOSITION.

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The method of chemical aerosol deposition has become a simple and inexpensive approach to the preparation of superconducting thin films. The best results are expected when the aerosol deposition is conducted in the regime of chemical vapor deposition because then very good homogeneity in the film growth with conse- quently the need of only a reduced temperature treatment can be expected. We used several metallorganic precursors; the best results were obtained with tetramethyl-heptanedione salts, $Y(TMHD)_3$, $Ba(TMHD)_2$ and $Cu(TMHD)_2$. These salts could be dissolved in the organic solvent n-butylacetate. The solution was sprayed with the aid of an ultrasonic nebulizer on a silicon substrate coated with a ZrO_2 buffer layer at a temperature of 450°C. After preparation, the following heat treatment was given: (1) warming up from 250°C to 800°C at the rate of 20°C/min under a flow of N_2 gas and then keeping the temperature 20 minutes at 800°C; and (2) slowly cooling down at a rate of 0.5°C/min under a flow of O_2 gas.

The structures of the films prepared in this way were analyzed by x-ray diffractometry. The good films exhibit an orthorhombic structure with the c-axis aligned perpendicular to the surface. The composition was determined by x-ray fluorescence and Scanning Auger Microscopy (including sputter depth profiles). In the best cases, SEM analysis reveals a homogeneous granular structure of the films, the size of the grains being 250 nm. The best films show superconducting transition temperatures for the onset and zero resistance of 95K and 75K respectively. There are studies in progress to use these films in light detection devices.

Notes

THERMOELECTRIC POWER IN SUPERCONDUCTING CERAMIC OXIDES.

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Thermopower (TEP) was measured with high resolution in a variety of high T_c superconducting ceramic oxides (YBaCuO, BiCaSrCuO and TiCaBaCuO types) as bulky ceramics, epitaxial thin films and single crystals, in order to get complementary information to resistivity data concerning the transport properties of these materials. TEP was found to be very sensitive to the oxygen content and to the chemical substitutions that can affect the Fermi level as in the case of Pr substitution for Y, in YBaCuO type superconductors. In a smaller extent TEP, it was also found sensitive to the crystallographic directions due to the anisotropy. In all cases, the observed temperature dependence is not accounted by the simple one electron models currently applied to metals and alloys putting in evidence the importance of the electronic correlation effects of the carriers that are confined to the narrow bands. Several transport models and their ability to account for the experimental results are reviewed.

Notes

MICROWAVE PROPERTIES OF HIGH T_C MICROBRIDGES.

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At microwave frequencies, Josephson junctions offer the possibility of sensitive broadband and spectral detection. For spectral detection, the junction is operated around the first Shapiro step. The microwave frequency determines the position of this step. The spectral resolution in the frequency selective mode of operation is mainly limited by noise in the junction which causes a broadening of the line width of the Josephson oscillation.

We have investigated the spectral resolution of microbridges with widths of about 10 μm which are lift-off structured from rf-sputtered YBaCuO polycrystalline thin films. These microbridges show clear Josephson-like behavior. The effect of microwave power on the IV-characteristics is measured using phase detection. After Hilbert transforming this result, the line width of the Josephson oscilla-tion is known.

At T = 4.2K, the results for the line width are comparable to those for classical superconductors. With temperature, the line width increases less than the linear relation which is in agreement with theory.

Notes

PREPARATION OF Bi-Sr-Ca-Cu-O SUPERCONDUCTOR PHASES: GLASS CRYSTALLIZATION VERSUS SINTERIZATION METHOD.

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The preparation of the Bi-Sr-Ca-Cu-O high temperature superconducting phases using the conventional solid state reaction and sintering methods usually gives a mixture of several phases with different critical temperatures. the amount of each phase critically depends on the preparation conditions and zero resistivity above liquid nitrogen is usually difficult to achieve, the critical currents being often small (<5 A/cm^2 at 77K). Glass crystallization is an alternate route to obtain high temperature superconductors of this family. Results of the study of crystallization of glasses with nominal composition 2223 made by microstructural x-ray diffraction analyses, DSC, transport and magnetic susceptibilty measurements are presented. High density multiphase samples with zero resistivity above 87K are easily obtained by treatment of glasses at 810°C. Lead and potassium doping in amounts as small as 1% increase the zero resistivity temperature and the fraction of high T_c superconducting phase in samples prepared by glass crystallization. Zero resistance at 98K and critical currents of 160 A/cm^2 at 77K are easily observed in potassium doped samples crystallized at 840°C.

Notes

ELASTIC AND ANELASTIC EFFECTS IN $GdBa_2Cu_3O_{7-\delta}$ AS A FUNCTION OF PRESSURE AND TEMPERATURE.

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The effects of hydrostatic pressure on the elastic properties of $GdBa_2Cu_3O_{7-\delta}$ are reported. Wave scattering theory in a porous medium has been used to take the effects of porosity into account. One particularly interesting result is that the pressure dependence $(\partial B/\partial P)_{p=0}$ has the very large value of 55. This explains why the adiabatic bulk modulus B^S_O measured ultrasonically at atmospheric pressure is much less than that $B^T(P)$ determined by x-ray measurements of the lattice parameters at high pressure. It is suggested that the comparatively small bulk modulus and its large pressure dependence could be due to a combination of variable copper valence and to sited vacancies in the crystal structure.

To elucidate further the elastic response of $GdBa_2Cu_3O_{7-\delta}$, ultrasonic velocity and attenuation measurements have been made in both its orthorhombic and tetrag-onal states at low temperatures. Softening of the elastic constants near T_c and a stiffe:ing below T_c have been shown to be caused by conventional an-harmonic and an-elastic phenomena. Relaxation peaks have been identified which are consis-tent with thermally activated oxygen vacancy migration processes. No effect which can be directly attributed to the formation of the superconducting state has been identified in the temperature dependencies of the ultrasonic velocity and attenuation.

Notes

EFFECTS OF OXYGEN STOICHIOMETRY ON SUPERCONDUCTING PROPERTIES OF THE CERAMICS $ABa_2Cu_3O_{7-\delta}$ WITH A = Yb,Y,Gd AND La.

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Samples of $ABa_2Cu_3O_{7-\delta}$ with A-atoms of different ionic radii were prepared in order to examine the dependence of the superconducting transition temperature and the crystal structure on the oxygen content. The transition temperature T_c was determined by standard four-probe resistivity and by susceptibility measurements, the structures were analyzed by powder x-ray diffraction.

All fully oxidized samples had a T_c above 90K. In dependence of the oxygen content T_c of $YbBa_2Cu_3O_{7-\delta}$, $YbBa_2Cu_3O_{7-\delta}$ and $GdBa_2Cu_3O_{7-\delta}$ showed a plateau at 50K - 60K, whereas T_c of $LaBa_2Cu_3O_{7-\delta}$ was sharply reduced even for small oxygen deficiency.

The results are related to the ionic radius of the substituted atoms.

Notes

MICROWAVE SURFACE IMPEDANCE MEASUREMENTS IN HIGH Tc MICROSTRIP TRANSMISSION LINES.

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The propagation characteristics of a thin film microwave transmission line are determined by the surface resistance and reactance of the superconducting films. We have constructed high T_c superconducting microstrip transmission lines using both in-situ and post-annealed films. The phase velocity and attenuation of these transmission lines have been measured as a function of temperature, frequency, excitation power and transmission line geometry. We find that the surface impedance of the high T_c films is sensitive to the preparation conditions of the films and is consistent with what one expects from a BCS superconductor in the clean limit.

Notes

PREPARATION OF $YBa_2Cu_3O_{7-\delta}$ BY SPRAY DRYING METHODS.

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The description of an apparatus for preparing precursors of high T_c superconductors by spray drying is given. Many methods for the preparation of precursors are conceived with subsequent technological design in mind. The spray drying technique possesses clear advantages in the production of bulk material and films or coatings. The light blue feedstock solution made from 99.9% pure $Y(NO_3)_3\ 6H_2O$, $Cu(NO_3)_2,3H_2O$ and $Ba(NO_3)_2$ can easily be sprayed onto many substrates, the method is fast and amenable to scale-up. Spray-dried precursors can be easily produced using readily available laboratory glassware and electrical appliances. The apparatus is represented schematically in Figure 1.

Such an apparatus allows the production of spray-dried $YBa_2Cu_3O_{7-\delta}$ precursors at a rate of 90 gh^{-1} and gives rise to high quality ceramic superconductors with minimal subsequent thermal treatments. Some minor improvements in the apparatus are at present being tested: the use of hot air as propulsing medium, applica-tion of small-aperture-high-pressure thermospray vaporizers such as those used in HPLC/MS.

The conclusion is that we have built a simple apparatus which is able to produce homogeneous, dense precursor with stoichiometrically correct metal distribution.

Notes

HYSTERESIS OF CRITICAL CURRENTS IN $YBa_2Cu_3O_{7-x}$.

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The low critical current density J_c in polycrystalline $YBa_2Cu_3O_{7-x}$ and its magnetic field dependence is generally understood in terms of weak links between the superconducting grains. Besides flux trapped in the weak link regions may affect J_c that will depend on the measurement conditions. We have investigated the hysteresis of the transport critical current under increasing and decreasing magnetic fields. Magnetic measurements suggest that hysteresis does not appear in the intergrain currents. Possible interpretations are given to explain the large hysteresis of J_c observed over a few tesla.

Notes

THE EFFECT OF PROCESSING PARAMETERS ON THE CHARATERISTICS OF $YBa_2Cu_3O_y$ SUPERCONDUCTORS.

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High T_c superconductor in the system Y-Ba-Cu-O was obtained as a single phase. Its composition was determined to be $YBa_2Cu_3O_y$. The compound is considered to be stoichiometric in regard to the Y-Ba-Cu ratio. We have studied the effect of the pelletizing pressure on the superconducting properties and the crystal structure. The characterization of the superconductivity was carried out by 4-point resistivity measurements. The particle size analyses were performed by using a scanning electron microscope. SEM studies also reveal a distinct difference in the morphology of the green, non-superconducting phase and the black, superconducting phase. The superconducting phase shows faceted growth steps on the rounded surfaces, whereas the non-superconducting phase is in interaction with the vapor phase during growth. We have performed detailed x-ray diffraction and electron diffraction analyses to study the nature of $YBa_2Cu_3O_y$ prepared at different pelletizing pressures. Increasing these pressures resulted in excellent densification, but limited superconducting properties. Low pelletizing pressures yielded porous specimens showing better electrical characteristics. To see the effect of pelletizing pressures in regard to the sintering temperature, the compacts of $YBa_2Cu_3O_y$ were sintered below and above 930°C is accompanied by some liquid-phase sintering, whereas sintering below 930°C occurs primarily by solid-state diffusion. The effects of varying pelletizing pressures at two sintering temperatures on the structures, morphology, and the electrical properties, namely, transition temperature (T_c) will be reported.

Notes

FORMATION AND CHARACTERIZATION OF $YBa_2Cu_3O_y$ SUPERCONDUCTOR THIN FILMS PREPARED BY SPUTTERING.

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We prepared superconducting Y-Ba-Cu-Oxide films using the technique of sputtering from a sintered superconducting target onto sapphire substrates in a vacuum chamber. As targets for the sputtering process we used 36 mm diameter, 2-4 mm thick pellets of the nominal composition $YBa_2Cu_3O_y$. They were prepared in the usual way by grinding and sintering from the powdery oxides Y_2O_3, CuO, and $BaCO_3$. The targets consist of single phase orthorhombic material with a critical temperature of about 90 K. The substrates used were sapphire slices of 10x10x1 mm size and the substrate temperature was maintained at the room temperature during deposition. During film growth black-grayish deposits were observed on the substrates which showed insulating characteristics. Electron diffraction and x-ray analysis showed that $YBa_2Cu_3O_y$ films obtained were amorphous. These films were annealed films were performed using standard four-probe technique and showed that they exhibited superconducting properties with a critical temperature of around 80 K. However, these annealed films had a larger transition widths compared to the targets used for sputtering. The structural studies (electron and x-ray diffraction) yielded that the annealed films were orthorhombic. The results for films of different thicknesses will be reported.

Notes

EFFECT OF FAST NEUTRON IRRADIATION DAMAGE OF 110 K PHASE OF Bi-Pb-Sr-Ca-Cu-O SYSTEM.

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Transport and magnetic properties were studied of polycrystalline Bi-Pb-Sr-Ca-Cu-O samples as a function fast neutron fluences since $1.6\ 10^{16}$ n/cm^2. Transport measurements indicated a depression of T_c/R=O/ since 102 K to 79 K after the irradiation with the highest fluence. Radiation damage causes increase of resistivity and the transition width. Transport critical current denities J_c data shows strong decrease in external magnetic field in the range from 0.5 to 5 Oe at temperature 77 K. Such behavior is caused by the strong degradation of superconductivity in the week link regions. This conclusin is supported by the low field magnetisation/below Hc1 grains/ measurements. Low field magnetization hysteresis curves, which are the respons of the week links an external magnetic field, decreases with the increase of fluences.
On the other hand, similar to the Y-Ba-Cu-O samples, high field magnetization data show on increase of irreversibility with the increase of fluence, what in therms of Bean's model is connected with the increase of the critical current density JcM/intragrain current/. This is explained by the improving of the pinning in the grains caused by the defects produced by fast neutrons.

Notes

SUPERCONDUCTIVITY IN MULTIPHASE Bi-Sr-Ca-Cu-O THIN FILMS DEPOSITED BY SINGLE RESISTIVE EVAPORATION SOURCE.

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High Tc superconducting Bi-Sr-Ca-Cu oxide thin films were evaporated in a conventional vacuum system utilizing a single resistively heated source. A well ground mixture of CaF_2 SrF_2, Cu and Bi weighed to yield a stoichometric $Bi_{2\ 3}\ Sr_{1.58}\ Ca,\ Cu_{3.94}$ film of about 1μm thickness was evaporated from a single tungsten boat onto a well polished $SrTiO_3$ and ZrO_2 substrates held at room temperature at a 6 cm distance above the boat. No thickness monitor or any other control distance above the boat. No thickness monitor or any other control system other than evaporation to completion was used in this experiment. Typical residual vacuum pressure was about 2.10^{-5} torr during evaporation time which altogether lasted for 30 minutes.

The films thus obtained were annealed in a preheated furnace at $725^{o}C$ for 15 minutes followed by 5 minutes at $850^{o}C$ in a flowing O_2 bubbledthrough water, and then cooled to room temperature within a few minutes. A conventional four-point probe electrical measurements with pressed indium contacts were used to study its resistivity versus temperture. The electrical properties were found to be quite sensitive to the annealing temperature and duration of moistening the oxygen. Accordingly, a wide range of onset and zero resistance temperatures were found. In some samples zero resistance was measured at 80K.

Notes

LOCALISATION EFFECTS IN RADIATION DISORDERED HTSC.

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The influence of disordering under fast neutron irradiation on the properties of HTSC is investigated. The prperties of high-T_c superconductors turn out to be strongly sensitive to disorder. The responce of the system to controlled introduction of defects helps to better understand the peculiarities of its electronic properties in the ordered state. It is well known that sufficient disorder may result in the metal-insulator transition due to electron localisation (Anderson transition). Quasi-two-dimensional systems to which the high-T_c superconductors belong are expected to show strengthening of effects of localisation that occurs at values of conductivity appreciably exceeding typical values of three-dimensional systems. We have investigated the influence of fast neutron irradiation at liquid nitrogen temperature on physical properties of YBCO, LSCO and BSCCO. Our experiments show that the properties of electronic system of HTSCs make them close to Anderson metal-insulator transition even in the ordered state. Radiation disordering results in oxygen distribution over sites 04 and 05 and growth of mean-quadratic atomic displacement. On the basis of experimental data we may assert that the chemical composition of HTSC in this case does not change and all effects result from the introduction of the chaotic potential only. For ceramic samples increasing extent of disorder leads to exponential temperature dependence of electrical resistivity. Besides that the value of p(80K) grows exponentially with fluence. To all appearence pairing takes place in the system of localised electrons even in slightly disordered samples. Superconductivity exists till the radius of localisation exceeds the typical size of the Cooper pair in hightly disordered system. For YBCO single crystals the radiation disorder leads to an exponential growth of resistivity with fluence at first in direction of Cu-O layers and to the decrease in anysotropy of resistivity at low temperature and hence weakening of its temperature dependence as well as to decrease in anysotropy of the upper critical field. It is also interesting that at low temperatures the Hall carriers concentration practically does not change under disorder while its temperature dependence is essentially weakened in the disordered HTSC.

Notes

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